Journal of Pedagogical Research
Volume 9, Issue 3, 2025
https://doi.org/10.33902/JPR.202533653

Research Article

Group discussions in secondary school chemistry: Unveiling pedagogical alchemy for academic advancement

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Chemistry education in Rwandan secondary schools faces challenges, especially after the adoption of a competence-based curriculum that prioritizes student-centered learning. Traditional teacher-centered approaches often result in poor student performance. This study investigates the impact of structured group discussions on chemistry achievement in senior high schools in Kigali, addressing gaps in student engagement. Using a mixed-methods quasi-experimental design, 50 students were divided into an experimental group (taught with group discussions) and a control group (taught with traditional methods). Data were collected via a Chemistry Achievement Test, student questionnaires, and interviews with 6 science teachers and 2 administrators. Quantitative data were mainly analysed using independent statistical t-tests, while qualitative data were thematically analysed. The findings showed that students in the experimental group significantly outperformed the control group, suggesting group discussions effectively enhance chemistry learning. Furthermore, the results from the effect size calculations suggest that group discussions had a meaningful positive impact on student performance in chemistry, indicating the effectiveness of this teaching strategy. The study also revealed that smaller group sizes (four to six students) promote more productive discussions, and that group discussions foster peer learning and deeper subject understanding. These results offer new insights into the benefits of group discussion in chemistry education, which have been underexplored in previous studies. This study suggests that integrating group discussions can improve both academic performance and student participation in chemistry classrooms.

Keywords: Chemistry; Evaluation; Group discussion; Science education; Teaching

Article History: Submitted 22 January 2025; Revised 4 March 2025; Published online 21 April 2025

1. Introduction

Inquiry-based learning (IBL) is a well-established approach in constructivist pedagogy, recognized for its role in promoting student exploration and discovery (Hmelo-Silver, 2004; Minner et al., 2010). However, implementing IBL often requires significant teacher scaffolding and resources, which may not always be feasible in secondary school settings (Kirschner et al., 2006). As an alternative, discussion groups serve as an effective strategy to enhance conceptual understanding, critical thinking, and collaborative learning in chemistry education. By fostering peer interaction, knowledge co-construction, and argumentation, discussion groups help students engage deeply with complex scientific concepts (Mercer & Howe, 2012; Oviedo, 2004). Additionally, they provide

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How to cite: Shyiramunda, T. (2025). Group discussions in secondary school chemistry: Unveiling pedagogical alchemy for academic advancement. *Journal of Pedagogical Research, 9*(3), 1-24. https://doi.org/10.33902/JPR.202533653

opportunities for active reasoning and conceptual clarification, aligning with socio-constructivist principles (Vygotsky & Cole, 1978).

Chemistry education in secondary schools, especially in developing countries, faces enduring challenges due to the abstract and complex nature of the subject. These difficulties are compounded by traditional teacher-centered teaching methods, which often fail to actively engage students, leading to underperformance in chemistry. Given chemistry's essential role in driving scientific innovation, technological advancements, and its relevance to various industries, addressing the gaps in chemistry education is urgent and crucial for national development (Sweeney-Lawson, 2024; Zuin et al., 2021). In Rwanda, the recent shift to a Competence-Based Curriculum [CBC] underscores the need for student-centered, interactive learning approaches that foster critical thinking and problem-solving skills (Juko & Njuguna, 2019). However, there remains a lack of effective strategies tailored to meet these objectives in chemistry education. This study is vital as it directly addresses the widespread underachievement in secondary school chemistry, which is attributed in part to the lack of engaging, interactive teaching methods. Research has long supported the benefits of collaborative learning, particularly in social sciences (Johnson & Johnson, 2009; Roseth et al., 2008). However, the application of such methods in the natural sciences, especially chemistry, remains underexplored (Allen et al., 2021). This presents a critical gap in the literature, providing an opportunity to explore the potential of group discussions as a pedagogical tool specifically in the chemistry classroom.

The current research aims to examine the impact of structured group discussions on student performance in chemistry education. The independent variable in this study is the use of structured group discussions, a pedagogical method designed to enhance interaction and critical thinking among students whereas dependent variable is student achievement in chemistry, measured through performance outcomes. The relationship between these variables is moderated by student engagement, a key factor that influences the effectiveness of group discussions. The theoretical underpinning suggests that increased student engagement, driven by active participation in group discussions, leads to improved comprehension and retention of chemistry concepts, which in turn enhances academic performance (Park et al., 2024). By focusing on these interconnected variables, the study establishes a clear, valid link between the teaching method (group discussions), the mediating factor (student engagement), and the outcome (student performance in chemistry).

Additionally, this research seeks to update and extend prior work by applying group discussions within the context of chemistry, a discipline often viewed as cognitively demanding due to its abstract concepts. While prior research (Adams, 2022) has explored group discussions broadly, there is little understanding of their specific impact on chemistry learning. By using a mixed-methods quasi-experimental design, the current study integrates both qualitative and quantitative data to provide a more comprehensive analysis of how group discussions influence student performance, engagement, and critical thinking in chemistry (Zuin et al., 2021). This advances the understanding of collaborative learning in STEM and provides actionable insights for educators and policymaker. The urgency of this research is further driven by Rwanda's national educational goals, which focus on fostering a knowledge-based economy through competency-based education reforms (Juko & Njuguna, 2019). Chemistry, being a core subject in the science curriculum, plays a pivotal role in equipping students with the skills needed for Rwanda's socio-economic development. Investigating how group discussions can improve chemistry outcomes aligns with these national priorities, making this research both timely and relevant.

The research questions guiding this study are as follows:

RQ 1) How does the implementation of group discussions influence student performance in chemistry compared to traditional teaching methods?

RQ 2) What strategies can be employed to effectively organize group discussions that enhance engagement and participation in chemistry classes?

RQ 3) How effective is the group discussion method in promoting student engagement and academic performance?

By addressing these questions, the current research not only fills a crucial gap in the existing literature but also contributes practical knowledge to inform teaching practices in chemistry education. The significance of this research lies in its capacity to offer evidence-based recommendations that can guide the integration of group discussions into chemistry classrooms, ultimately improving student engagement and academic outcomes. Thus, the study advances current knowledge by demonstrating that structured group discussions can serve as an effective pedagogical tool for improving chemistry education. The research further brings a novel, discipline-specific perspective to collaborative learning strategies and provides a substantial contribution to educational practices, particularly in the context of developing countries like Rwanda where there is ongoing educational reforms.

Definitions of the related concepts are summarized as follows. Group Discussion [GD] involves a collective dialogue focused on a specific topic, enabling participants to share ideas, debate different viewpoints, and gain a deeper understanding through interaction. In this setting, students collaborate to address problems and learn from one another (Parmar, 2022). Group Learning is a broader concept where multiple students participate in shared tasks and engage with one another to enhance their individual learning experiences through knowledge exchange (Johnson & Johnson, 2009). While Group Discussion emphasizes dialogue and exploration of perspectives on a specific issue, Group Learning encompasses any collaborative activity aimed at mutual educational benefits. Peer Learning refers to interactions among individuals with similar academic levels, where they share knowledge, give feedback, and support each other throughout the learning journey (Topping, 2005). Peer Learning is more focused on the reciprocal support among equals in a learning environment, often within the context of Group Learning. Cooperative Learning refers to a structured and systematic approach to small group instruction, facilitated by a teacher, allows students to collaborate in small teams to achieve shared learning objectives effectively (Garfield 1993; Johnson & Johnson, 1987; Slavin, 1980). Collaborative learning differs from cooperative learning in that it is a more flexible (unstructured) form of small-group instruction. It employs various formal and informal teaching methods, allowing students to engage interactively within small groups as they work towards shared objectives (Dillenbourg, 1999; Roseth et al., 2008; Springer et al., 1999). Springer et al. (1999) described collaborative learning as a relatively informal process wherein participants collaboratively set goals, identify issues, develop methodologies, and create knowledge through social interactions in small groups. Inquiry-based learning is an instructional approach that encourages small groups of students to collaboratively investigate problems or inquiries. Students engage in activities such as exploring, asking pertinent questions, conducting investigations, and sharing their findings with classmates, ultimately culminating in the creation of a scientific report (Chiappetta, 1997; National Research Council, 1996). In this type of learning environment, students actively interact with a specific scientific issue before acquiring the relevant vocabulary, concepts, and content associated with the inquiry (Chiappetta, 1997). Based on the nature, scope, and purpose of our study, we decided to use group discussion as it fosters active participation, encourages critical thinking and facilitates in-depth exploration of topics through dialogue, making it an ideal method for achieving our research aim.

2. Theoretical Framework

This study is grounded in the constructivist theory of learning, which holds that learners actively construct their own understanding through interaction with prior knowledge and new experiences. Constructivism, as outlined by Kassem (2000) and Meyer (2004), emphasizes that students are not passive recipients of information but active participants who build knowledge by engaging with content and reflecting on their learning experiences. This theoretical perspective is particularly relevant to the teaching and learning of chemistry, where abstract concepts often

require learners to integrate prior knowledge with new information to develop a deeper understanding.

In chemistry education, the constructivist approach supports the idea that learners must engage with complex scientific concepts through active participation and collaboration. This study leverages constructivism by focusing on group discussions as a method to facilitate this process. Group discussions provide students with opportunities to negotiate meaning, share perspectives, and engage in problem-solving, which are essential elements of constructivist learning environments (Loyens & Gijbels, 2008). By allowing students to co-construct knowledge, the group discussion method fosters deeper cognitive engagement and enhances comprehension of difficult chemistry topics. To expand on the constructivist foundation, this study integrates additional theories that highlight the social and cultural dimensions of learning, which are critical for understanding the full impact of group discussions in a classroom setting. Vygotsky's sociocultural theory (Vygotsky & Cole, 1978) emphasizes the importance of social interaction in cognitive development. According to Vygotsky, learning occurs through collaborative activities where more knowledgeable peers help scaffold the learning process. In the context of this study, group discussions are a practical application of Vygotsky's theory, where students engage in collaborative exchanges that facilitate the construction of new knowledge through interaction with peers and the chemistry content.

Piaget's constructivism further complements this approach by underscoring the active role of learners in adapting their mental models through experiences (Piaget, 1970). Group discussions allow students to test their ideas, encounter different perspectives, and refine their understanding based on peer feedback. This aligns directly with the objectives of this study, which aims to investigate how peer-led discussions influence students' grasp of chemistry concepts and enhance their ability to apply scientific reasoning. Bandura's social learning theory (Bandura, 1977) also informs this study by explaining how students learn from observing and modeling the behavior and problem-solving approaches of others. Within group discussions, students have the opportunity to observe how peers tackle chemistry problems and model successful strategies, which can lead to improved critical thinking and problem-solving skills. This theory is particularly relevant to the study's goal of examining the impact of group discussions on student achievement in chemistry. Wenger's communities of practice (Wenger, 1998) and Lave and Wenger's situated learning theory (Lave & Wenger, 1991) provide additional support for the study's focus on group discussions as a learning tool. These theories emphasize that learning is a social process that takes place in communities where individuals share practices and knowledge. In this study, group discussions serve as a community of practice in which students collaboratively engage with chemistry content, exchange ideas, and participate in authentic scientific inquiry, all of which contribute to deeper learning.

2.1. Connection to This Study

This study applies these theoretical perspectives to investigate how group discussions, as a constructivist and collaborative learning strategy, influence student performance in chemistry. The central research questions focus on the effectiveness of group discussions in improving student comprehension and engagement with inorganic chemistry concepts. By integrating Vygotsky's sociocultural theory and Piaget's constructivism, this study recognizes the importance of social interaction and active engagement in facilitating meaningful learning. Additionally, Bandura's social learning theory and Wenger's communities of practice provide a framework for understanding how students learn from and with their peers during group discussions, which is central to the study's inquiry into student achievement.

Grounded in Vygotsky's sociocultural theory, Piaget's constructivism, Bandura's social learning theory, and Wenger's communities of practice, the study addresses three research questions (RQ1, RQ2 and RQ3). Vygotsky emphasizes the role of social interaction in cognitive development, while Piaget highlights the active construction of knowledge through experience. Bandura's theory

focuses on learning through peer interactions, and Wenger illustrates the benefits of collective learning. Together, these theories provide a comprehensive framework for understanding how group discussions can enhance student engagement, comprehension, and academic success in chemistry education.

2.2. Exploring Group Discussions, Student Performance, and Effective Strategies for Facilitating Group Conversations

This section is intricately linked to the research questions and the overall scope of the study, which revolves around the effectiveness of structured group discussions in enhancing student achievement in inorganic chemistry at the high school level. The insights provided here directly address key aspects of the research questions, shedding light on the dynamics of collaborative learning and effective strategies for facilitating group conversations in the context of chemistry education. The literature presented emphasizes the positive impact of peer-led small-group discussions on student motivation, engagement, and comprehension (Fukuzawa et al., 2017; Wu et al., 2013). As the first research question explores the extent to which structured group discussions enhance student achievement, these findings offer valuable context and support for the anticipated outcomes of the study.

Additionally, the discussion on effective strategies for organizing group discussions is directly aligned with the second research question, which seeks to identify strategies that can be employed to organize effective group discussions in chemistry classes. The highlighted techniques, such as random selection and compatibility in scheduling, provide practical insights that can inform the design and implementation of our structured group discussions. Furthermore, the connection between collaborative learning and student performance, as discussed by Kirschner et al. (2018) and Lyall and Meagher (2012), directly addresses the research questions related to the potential of group discussions to promote active student participation and enhance achievement in the specific context of inorganic chemistry.

A substantial body of literature has demonstrated that involving students in collaborative learning through peer-led small-group discussions leads to increased levels of student motivation in contrast to traditional teaching and learning approaches heavily reliant on teachers (Wu et al., 2013). An earlier study conducted by Fukuzawa et al. (2017) in the context of problem-based learning [PBL] revealed that students actively engage in assigned tasks due to their motivation to work on collaborative projects. Group discussions prove to be an effective method for imparting soft skills to students through peer-led teaching and learning. Through this pedagogical approach, students develop organizational skills relevant to teamwork and collaboration, as demonstrated in the work of Sancho-Thomas et al. (2009). Effective group discussions also foster skills such as active listening, clarification of statements and perspectives, conflict mediation, and the ability to summarize and present outcomes, as highlighted by Gillies (2003).

There is a discernible link between student performance and the extent of collaborative learning employed, as observed in the research by Kirschner et al. (2018). When students share common goals and are open to discussing their experiences, they are more likely to comprehend challenging scientific concepts, as identified by Lyall and Meagher (2012). In larger classes, employing techniques such as random selection, compatibility in scheduling, or instructor selection based on preclass questionnaires may be effective and perceived as fair by students, in line with the insights of Gross Davis (1999). According to Gross Davis (1999), students are more engaged in their educational journey when they work in small groups and benefit from timely feedback. While students sometimes require assistance in understanding assignments, they also frequently seek guidance and motivation, particularly at the outset, to ensure that they are on the right course. Teachers can offer valuable suggestions and potentially realign the group's efforts by inquiring about the overall strategy. However, it remains essential to empower students to make their own decisions when providing feedback during group projects. The instructor's role is to guide group members rather than impose solutions. For instance, if a group member raises

concerns about someone not contributing their fair share, it should be emphasized that the group is responsible for finding a resolution, and the instructor should not intervene to resolve the issue.

In essence, the above section lays the groundwork for understanding the intricate relationships among group discussions, student performance, and effective strategies. It serves as a theoretical foundation that informs the design and implementation of the current study, offering insights into how structured group discussions can be optimally leveraged to achieve the research objectives in the realm of high school inorganic chemistry education. The next section describes the materials and methods.

3. Materials and Methods

3.1. Research Design

The current research adopts a mixed-methods approach, integrating both quantitative and qualitative data collection techniques to provide a comprehensive understanding of the impact of group discussions on chemistry learning outcomes. Mixed methods were chosen because they allow for the combination of the strengths of both quantitative precision and qualitative depth, making it possible to cross-validate and triangulate the findings (Creswell & Plano Clark, 2017).

Using quantitative data, such as test scores, allowed us to measure statistically significant improvements in student performance, while qualitative insights from interviews and questionnaires provided context to understand the practical dynamics of group discussions. This aligns with Tashakkori, et. al (2012) assertion that mixed-methods designs provide a fuller picture of complex phenomena. Further, Greene (2007) support the use of mixed methods for enriching the explanation of results, particularly when studying educational interventions. Bryman (2016) highlights how this approach helps in gaining a more holistic understanding of research questions, especially in pedagogical studies like ours.

Mixed methods were especially appropriate here because group discussions affect measurable performance while also influencing students' attitudes, engagement, and collaboration, aspects best explored qualitatively (Creswell & Creswell, 2017). The quasi-experimental design was chosen for its practicality in real-world educational settings, allowing the comparison of an experimental group (group discussion) and a control group (traditional teaching) without random assignment, as noted by Campbell, & Boruch (1975).

3.2. Sample and Sampling Method

A purposive sampling method was used to select participants for the study. Purposive sampling, as described by Patton (2002) and Creswell and Plano Clark (2017), is particularly useful when researchers need participants that fit specific criteria essential to the study's objectives. In this case, the sample comprised 50 secondary school students (26 males and 24 females) from a secondary school in Kigali, Rwanda, who were enrolled in their second year of study. The gender balance was deliberate to ensure a fair comparison across demographics. The sample was divided into two groups: Control group (n = 25): Students receiving traditional lectures and Experimental group (n = 25): Students engaged in group discussions. This division aligns with Ameringer et al. (2009) guidelines on selecting equal-sized groups for quasi-experimental designs to control for extraneous variables. Additionally, six chemistry teachers, head teachers, and directors of studies participated in interviews to gain further insights into the impact of group discussions on chemistry learning.

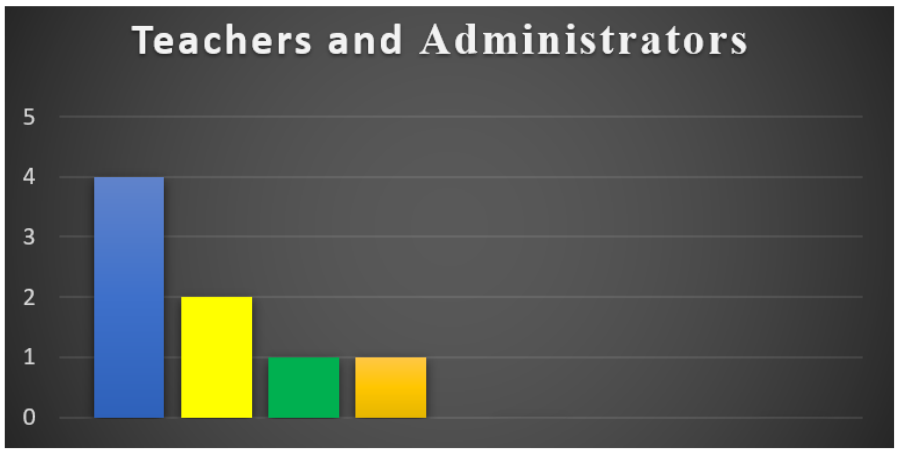
The purposive sampling technique was employed for its convenience and the voluntary nature of participation among the participants, as the researcher was engaged in a professional internship, which facilitated access to colleagues and students. This approach aligns with previous research methodologies that emphasize the importance of accessible and cooperative study populations to enhance the validity and reliability of educational research (Creswell & Creswell, 2017). Data in Table 1 show that the student participants were balanced in terms of gender, with 24 females (48%) and 26 males (52%), and predominantly aged between 12 and 15 years (64%). The sample was

divided into two groups: a control group (Classroom A) and an experimental group (Classroom B), each comprising 25 students. This demographic diversity allowed for a comprehensive analysis of the effects of group discussions on different subsets of students, reflecting findings from previous studies that underscore the importance of considering demographic variables in educational research (Smith et al. 2005). The involvement of teachers and administrators with varying levels of experience and expertise, as well as balanced gender representation among educators, was crucial (see Figure 1). The teaching experience among science teachers varied, with four male teachers having more than three years of experience and two female having less than three years. The head teacher (female) had ten years of experience, and the director of the studies (male) had seven years of teaching experience. This variation in experience is consistent with studies that highlight the influence of teacher expertise on student outcomes (Hattie, 2008).

Table 1
Demographic profile of study participants

	f	%
Gender		
Boys	26	52%
Girls	24	48%
Age		
> 12 ≤ 15 years	32	64%
> 15 years	18	36%

Figure 1
Teachers and administrators participated in the study



Legend: **Blue** = Teachers with more than 3 years, **Yellow**: Teachers with less than 3 years
Green = Headteacher (10 Years), **Orange**: Director of Studies (7years)

The strategic selection of the sample population provided a robust foundation for examining the impact of group discussions on students' chemistry learning outcomes. This approach aligns with the findings of Johnson and Johnson (2009) and Eom et al. (2006), who demonstrated the effectiveness of collaborative learning in enhancing academic performance. The study's design also mirrors the methodologies used by Adams (2022) and Steinert (2004), who investigated the role of group discussions in different educational contexts. It offers practical insights for educators on how to implement group discussions to improve student engagement and learning outcomes, thereby addressing a gap in the literature regarding the exclusive efficacy of group discussions in teaching natural sciences, particularly chemistry (Johnson & Mighten, 2005; Strayer, 2012).

3.3. Instruments

The key instrument for measuring student outcomes was the Chemistry Achievement Test [CAT], which employed a pretest-posttest design to assess students' comprehension of "types of reactions." The test was scaled to 20 points to ensure consistency in scoring, facilitating a clear evaluation of the progress made by both the control and experimental groups under different instructional approaches (Shyiramunda, 2023).

The content of the CAT was firmly grounded in inorganic chemistry, focusing on the properties and behaviors of compounds lacking carbon–hydrogen (C–H) bonds. The questions were carefully developed in alignment with the national secondary-level chemistry curriculum, with a particular emphasis on chemical reactions, as detailed in the sample lesson plan (Appendix 3). The administration of the CAT followed a phased approach: an initial diagnostic test before the intervention to establish baseline knowledge, a formative test administered during the instructional period, and a summative test at the conclusion of the intervention. This staged methodology adheres to well-established educational research practices for effectively tracking student learning progression (Black & Wiliam, 2018).

The instructional period lasted 40 days, totaling 80 instructional hours for each group, with an additional 10-day revision period. The control group was taught using traditional lecture-based methods, while the experimental group engaged in structured group discussions. Both groups were assessed using the CAT, with pretest data establishing a baseline and posttest data used to evaluate the effect of the group discussions on student achievement. All data collected were systematically recorded and organized in an Excel datasheet for subsequent analysis (Shyiramunda, 2023). The validity and reliability of the CAT are discussed in detail in the section titled Validity and Reliability.

3.4. Validity and Reliability

This section outlines how the validity and reliability of the research instruments, specifically the Chemistry Achievement Test, questionnaires, and interviews, were established for both the quantitative and qualitative components of the study. The integration of multiple instruments required a rigorous validation process to ensure the accuracy, consistency, and credibility of the data collected. Each tool was meticulously assessed to verify its appropriateness for measuring the intended outcomes.

3.4.1. Quantitative part: CAT and Questionnaires

Validity. To establish content validity for the CAT, a comprehensive review process was conducted. The test items, initially designed by the researcher, were subjected to evaluation by four subject matter experts in science and chemistry education, all holding master's degrees. These experts critically assessed the relevance, appropriateness, and alignment of the items with the learning objectives set out in the national chemistry curriculum. This expert validation process ensured that the CAT accurately measured students' understanding of chemical reactions, particularly the "types of reactions" subtopic, as outlined in the sample lesson plan (Appendix 3). The validation process adhered to recognized educational assessment standards (Haynes, Richard, & Kubany, 1995; Lin et al., 2013; Messick, 1995), providing robust evidence of the test's content validity. Similarly, the questionnaire items were carefully developed to measure student perceptions and engagement with group discussions. The content validity of the questionnaire was reinforced through expert review, where the questions were scrutinized for their ability to capture the intended constructs.

Reliability. The reliability of the CAT was verified through a two-step process. First, the test was administered twice to two groups of master's students from the University of Rwanda's African Center of Excellence for Innovative Teaching and Learning Mathematics and Science. The consistency in responses across these two administrations confirmed the test's reliability. Moreover, the questionnaire used achieved strong internal consistency, as evidenced by a

Cronbach's alpha coefficient of 0.887, indicating high reliability (Crocker & Algina, 1986). The pretest-posttest design of the CAT further enhanced the reliability of the findings by allowing for a direct comparison of performance across the control and experimental groups, minimizing potential biases.

3.4.2. Qualitative part: Interviews

Validity. For the qualitative component, semi-structured interviews were conducted with teachers, administrators, and students. To ensure the credibility and trustworthiness of the qualitative data, the interview guides were developed following an extensive literature review and consultations with experts in education and chemistry. This iterative process ensured that the questions were both relevant and meaningful, providing valid insights into the participants' experiences with group discussions and chemistry teaching methods. Pilot interviews were conducted to refine the interview questions and enhance the clarity and focus of the interviews.

Reliability. The reliability of the qualitative data was addressed through member checking and triangulation. Member checking involved sharing the interview transcripts with participants to ensure the accuracy of their responses. Additionally, triangulation was employed by comparing the qualitative insights from the interviews with the quantitative findings from the CAT and questionnaires. Therefore, the validity and reliability of both the quantitative (CAT, questionnaires) and qualitative (interviews) instruments were rigorously established. The CAT and questionnaires underwent expert validation and achieved high reliability through statistical measures, while the qualitative interviews were validated through careful development and confirmed for reliability through member checking and triangulation. This rigorous process ensured that the findings of study are both credible and dependable, contributing valuable insights into the impact of structured group discussions on chemistry education.

3.5. Data Collection

To comprehensively assess the effectiveness of structured group discussions in enhancing chemistry learning outcomes, a mixed-methods approach was employed, incorporating both quantitative and qualitative data collection tools. The Chemistry Achievement Test served as the primary quantitative instrument. Administered as a pretest and posttest, the CAT evaluated students' knowledge and understanding of chemical reactions, specifically focusing on types of reactions. This standardized assessment provided measurable data on academic performance, enabling a comparative statistical analysis between the experimental group, which participated in structured group discussions, and the control group, which received traditional instruction. Further details regarding the development and implementation of the CAT are provided in the previous section titled Measurement. To capture students' perceptions of the effectiveness of group discussions, a structured questionnaire was distributed. This instrument allowed for the quantification of students' attitudes, experiences, and feedback regarding the teaching and learning process. It specifically assessed the influence of group discussions on their chemistry performance and the techniques used for organizing pair and group work.

In addition to the quantitative instruments, semi-structured interviews were conducted with teachers, headteacher, and director of studies to gather qualitative insights. These interviews aimed to provide a deeper understanding of teachers' and administrators' observations related to group discussions and their impact on student performance. The interview guides were meticulously developed based on prior research and expert consultation, focusing on key aspects such as the perceived effectiveness of group discussions and the feasibility of implementing such strategies within a competency-based curriculum. The interview guide for teachers consisted of four self-designed prompts while the guide for headteacher and director of studies included three self-designed prompts to capture their views on the topic under study (Appendix 2). This qualitative methodology aligns with established practices in educational research, as highlighted by Johnson and Mighten (2005), and Strayer (2012). Such an approach emphasizes the importance

of capturing educator attitudes and beliefs, which play a critical role in shaping instructional practices. The inclusion of statements for headteacher and director of studies also acknowledges the significance of administrative perspectives in influencing educational practices, as noted by Hargreaves and Fullan (2015).

The combination of these diverse data collection instruments facilitated the assembly of a robust dataset, enabling a comprehensive exploration of the research questions. The quantitative insights from the questionnaire provided valuable information on students' perceptions of the teaching-learning process and the impact of group discussions on their performance in chemistry. In contrast, the qualitative interviews offered deeper insights into educators' and staff members' perspectives, enriching the overall findings of the study. To evaluate the significance of differences between pretest and posttest scores on the chemistry learning tests for the experimental and control groups, the statistical independent-samples t-tests were applied. The posttest served as the intervention measure aimed at discovering how the intervention enhanced student comprehension and, subsequently, improved academic performance.

3.6. Data Analysis

Quantitative statistical analysis was performed using independent-samples t-tests to compare pretest and posttest scores between the experimental and control groups. Qualitative data were coded and analyzed to identify themes related to the implementation and perception of group discussions. The integration of both data types enhances the study's reliability and provides a multifaceted exploration of group discussions' impact.

The analysis of students' pretest and posttest scores, along with the examination of constructs expected to assess the effectiveness of group discussions in chemistry learning, was conducted using Excel, aligning with previous research that has utilized statistical software for data analysis (Field, 2013). The analysis was grounded in the raw data collected from students' chemistry achievement tests (see Appendix 4) and was informed by ten constructs outlined in Appendix 1, which emerged from the theoretical framework guiding the study. This approach reflects a systematic and rigorous methodology consistent with established research practices in educational assessment and evaluation (Saxton et al., 2014). The integration of qualitative insights from interviews (see Appendix 2) into the analysis process is noteworthy, as it adds depth and richness to the interpretation of quantitative results. The methodological approach aligns with the principles of mixed-methods research, which advocates for the triangulation of data sources to provide a comprehensive understanding of complex phenomena (Creswell & Creswell, 2017). By coding and organizing perspectives from interviews based on the main research questions, the study sought to bridge the gap in science education regarding the understanding of the group discussion process during teaching and learning. To ensure that the results of the intervention were meaningful, the effect size was further calculated using Cohen's d (Cohen, 1988), which measures the magnitude of differences between the experimental and control groups' performance on the posttest. Effect size offers insight into the practical significance of the findings, beyond just statistical significance. Cohen suggests that effect sizes of 0.2 are considered small, 0.5 medium, and 0.8 or higher large (Sullivan & Feinn, 2012, p.280).

Quantitative analysis of pretest and posttest scores and qualitative insights from interviews enhances the validity and reliability of the study findings, as it allows for a multifaceted exploration of the research topic (Creswell & Plano Clark, 2017). Moreover, the incorporation of qualitative data adds contextual richness and provides valuable insights into the mechanisms underlying the observed quantitative outcomes.

3.7. Research Sequence

The researcher's process of implementing group discussion methods is presented in Table 2. As indicated, four primary activities were central to the execution of this research: 1) identifying the core issue, 2) developing strategies, 3) conducting teaching sessions, administering tests, and evaluating them, and 4) recording and summarizing the final research outcomes.

Table 2
Sequence of research activities

Topic/Problem	*Activities/Strategies*	*Participants*
Problem identification About effects of group discussion on students' performance in Chemistry.	-Teaching and assessing students, observing how students participate, and interact with each other in learning process. -Group works and students' oral presentations. -Provision of homework.	Chemistry teacher and students of senior two.
Setting strategies and implementing them. Ensuring group discussion method and participation of Learners in Chemistry	-Cooperation among students, and use of group discussion method. -Improvisation. -Data collection	Chemistry teacher and students of senior two.
Setting of first term Chemistry Examination. Implementation of strategies to organize pair and group work in chemistry.	Giving examinations to students, marking and make comments about their performance.	Teachers and students of senior two.
Lack of laboratory and laboratory materials Use suitable methods of teaching chemistry such as group discussion.	Improvisation of locally available materials Inquiry method, story-telling, assigning and monitoring homework's to students and assessing students in order to know their improvement in Chemistry.	Teachers Learners, interns Chemistry teacher and students of senior two.
Improving students' performance, promoting scientific club at school and encouraging students to work in groups.	-Brief Literature Review (Concentrating on the problem and Research) -Library documentation, Internet, Questionnaires. - Design of study, Target group, Interviews, Data collection through questionnaires and their interpretations	Students, teachers and school administrators.
Improving performance of S2 (Senior two) students toward chemistry through cooperative discussion.	Encourage students of S2 to work in groups and discuss about chemistry topics given to them in small groups, general individual evaluation.	Chemistry teacher and students of S2.
Writing final issues on research topic	Findings, Conceptualization of Research, General conclusion and Recommendations	Researcher

4. Results

This section provides a comprehensive analysis of the study's findings, drawn from both quantitative and qualitative data collection methods. Insights were gathered through a combination of questionnaires and structured interviews with participants, offering a detailed perspective on the research questions. Additionally, statistical analyses of the control and experimental groups' performance are included, highlighting key differences and trends. The demographic profile of participants, outlined in Table 2, sets the context for interpreting these results. In this section, data is presented to directly address the research questions, offering transparent findings that establish a solid foundation for the subsequent discussion section.

4.1. Research Question 1

Table 3 presents data on students' performance before, during, and after the implementation of group discussion methods in chemistry classes (More details and records are provided by Shyiramunda, 2023).

Table 3
Students' Performance in Diagnostic (Pre-Intervention), Formative (During Intervention), and Summative Examinations (During Intervention)

Types of Tests, number and Groups			*Students 'Performance*		
Type of test	*Test Number*	*Group*	*Students with HRM (above 70%)*	*Students with MRM (Between 50% - 70%)*	*Students with LRM (below 50%)*
Diagnostic Test (DT)	DT-1	CG	15%	15%	70%
		EG	10%	20%	70%
Formative test (FT)	FT-1	CG	15%	20%	65%
		EG	40%	10%	50%
	FT-2	CG	10%	30%	60%
		EG	60%	10%	30%
Summative test (ST)	ST-1	CG	45%	15%	40%
		EG	90%	5%	5%

Note. CG: Control Group; EG: Experimental group; HRM: High Range Marks; MRM: Middle Range Marks; LRM: Low Range Marks.

Table 3 shows data on students' performance before, during, and after the use of group discussion methods in chemistry classes. The performance is categorized into three levels: High-Range Marks [HRM] (scored above 70%), Medium-Range Marks [MRM] (between 50% and 70%), and Low-Range Marks [LRM] (below 50%). The diagnostic test (pre-intervention) revealed that in the control group [CG], only 15% of students achieved HRM (scored above 70%). Similarly, in the experimental group [EG], just 10% attained HRM, while 70% fell into LRM (below 50%). This initial data indicates that both groups had a similar low-performance baseline before the intervention.

However, during the formative tests (FT-1 and FT-2), the experimental group (EG) demonstrated significant improvement, with HRM increasing from 40% in FT-1 to 60% in FT-2, and a sharp decline in LRM to 30% in FT-2. Conversely, the control group (CG) showed minor improvements, with only 10% reaching HRM in FT-2, indicating less significant progress compared to EG. By the summative test (ST-1), the results highlight the substantial impact of the group discussion method. The EG showed a dramatic increase, with 90% of students achieving HRM, and only 5% in LRM. Meanwhile, in the CG, 45% achieved HRM, but 40% remained in LRM. This comparative data clearly illustrates that the implementation of group discussion methods significantly improved student performance in chemistry compared to traditional methods.

4.2. Research Question 2

Tables 4, 5, and 6 shed light on the strategies for organizing effective group discussions, based on feedback from students and teachers.

Table 4
Student feedback on approaches employed for facilitating productive group Discussions

Criteria Used	*Frequency of Participants*	*Percentage (%)*
Based on academic interests	3	6
Based on intellectual abilities	9	18
Based on how students are sitting	36	72
Other strategies	2	4
Total	50	10

Table 4 shows how group discussions were organized, with 72% of students stating that the grouping was based on how students were seated, while 18% felt that groups were formed based on intellectual abilities, and 6% cited academic interests. These findings suggest that seating arrangements played a major role in group formation, although a more deliberate strategy could enhance group dynamics.

Table 5
Students' Desired Collaborative Teams

In Which Group Do You Like to Work in?	*Frequency of Participants*	*Percentage%*
Group of two students (pair work)	4	8
Group of 4-6 Students	44	88
Group of 6-8 Students	2	4
Group of 8-10 students	0	0
Other	0	0
Total	50	100

Table 5 presents students' preferences for group sizes. A large majority (88%) preferred working in groups of 4-6 students, with only 8% favoring pairs. This indicates a preference for medium-sized groups, possibly because they strike a balance between collaboration and individual accountability.

Table 6
Educators' Preferred Approaches for Group Member Selection

In Group Formation	*Frequency*	*Percentage (%)*
Students are allowed to select members of the group	0	0
Teacher selects randomly group members.	41	82
Teacher and students participate in group formation	9	18

Table 6 reflects educators' perspectives on group formation. It shows that 82% of teachers preferred to select group members randomly, while 18% involved both the teacher and students in the group formation process. Notably, none of the teachers allowed students to self-select their group members, perhaps to avoid bias or imbalance in group capabilities. These findings suggest that seating arrangements and random selection are common strategies employed, with medium-sized groups being most effective from the students' point of view.

The above results are consistent with the results from interview about group members selection procedure and group size (number of members per group):

> …I believe that group discussions should be the favored teaching method for enhancing learner performance and I've found that employing random selection and structuring groups based on students' seating arrangements is an effective strategy for organizing these activities. Moreover, creating groups of four to six students works better than having just two or larger groups, as they foster better engagement and collaboration among learners… (Interview with a Chemistry Teacher-T.1).

In an interview, another teacher shared his approach to forming student groups, emphasizing the importance of fairness. He explained that:

> I always use random selection for the sake of fairness when I group students for discussions in my lessons. I usually keep the groups between three to six members because I find that size to be the most effective for teaching and learning. I never use larger groups, but I must admit, sometimes I do when I'm feeling tired and don't have the time to manage many groups… (Interview with a Physics Teacher-T.5).

He laughed at this admission, illustrating the challenges teachers face while striving to maintain effective group dynamics.

4.3. Research Question 3

Table 7 shows the students' feedbacks regarding the advantages of group discussions.

Table 7
Students' Feedback on the Advantages of Employing Group Discussion

Benefits of using group discussion	*Frequency*	*Percent (%)*
Development of higher-level thinking, social skills and oral communication.	11	22
Deep understanding of the lesson due to different ideas of group members	28	56
preparation of real social life and employment situations	1	2
promotion of teacher and learner cooperation	7	14
Increase in learner engagement, commitment and initiative.	3	6
Total	50	100

Table 7 provides insights into students' perceptions of the benefits of group discussions. The majority of students (56%) believed that group discussions fostered a deeper understanding of the lesson through the exchange of diverse ideas among group members. Additionally, 22% recognized that group discussions promoted higher-level thinking and oral communication skills, while 14% highlighted the benefit of improved cooperation between teachers and learners (Table 7). A small percentage (6%) noted increased learner engagement, commitment, and initiative. These responses suggest that group discussions significantly enhance cognitive and social aspects of learning.

Table 8 and 9 address the group statistics and the impact of group discussions on student engagement and academic performance, respectively.

Table 8
Group Metrics and

Group Statistics					
Groups	*Observations*	*Mean*		*SD*	
		Pretest	*Posttest*	*Pretest*	*Posttest*
Control Group	25	7.080	7.400	2.914	3.452
Experimental Group	25	6.840	10.360	4.422	4.357

Table 9
Independent Samples t-tests for the Experimental and Control Groups

Scores	*Levene's Test*			*t-test for equality of means*			
	F	*t*	*p*	*df*	*MD*	*SED*	*p*
Pretest	5.384	.227	.025	48	.24	1.06	.822
Post-test	.258	−2.66	0.814	48	−2.96	1.11	.01

Note. MD: Mean difference; SED: SE Difference

Table 9 further demonstrates the effectiveness of group discussions through statistical analysis. The independent samples *t*-test for pretest and posttest scores revealed significant differences

between the experimental and control groups. In the post-test, the experimental group, which employed group discussions, achieved a mean score of 10.36 compared to 7.4 in the control group. The *t*-test results ($t = -2.662$, $p = 0.01$) indicate a statistically significant improvement in the experimental group's performance, further supporting the effectiveness of group discussion as a pedagogical tool. Furthermore, during the interview, when asked about the various teaching methods, the headteacher said:

> …In my experience, while all teaching methods have their merits, I find that the group discussion method stands out as the most effective for enhancing students' performance. It not only encourages student engagement but also fosters critical thinking and collaboration among learners. When students participate in group discussions, they actively share their ideas and clarify concepts with one another, which significantly enhances their understanding of the subject matter. This method allows students to take ownership of their learning, making it a powerful tool for improving academic performance…" (Interview with a Headteacher-Admin).

Finally, the effect size of Cohen's *d* was calcuted to determine the magnitude of differences between the experimental and control groups' performance on the posttest. The calculated values indicated a pooled standard deviation of 3.93 and a Cohen's d effect size of 0.75. This suggests that group discussions had a meaningful positive impact on student performance in chemistry, indicating the effectiveness of this teaching strategy.

5. Discussion

The study involved a diverse group of participants, including both male and female students from different age groups, specifically those aged 12 to 15 years and those older than 15 years. 6 sciences teachers and 2 administrators have also participated in the study (see Figure 1). This diversity enhances the generalizability of the findings, ensuring that the results are applicable across a broad demographic spectrum. As indicated in Table 2, there was a slight male predominance (52% male, 48% female); however, this difference is not significant enough to impact the outcomes. Both genders were well-represented, contributing to the robustness of the findings, which align with previous studies, such as Pfeiffer and Butz (2005), that emphasize the importance of gender-balanced samples for increasing the applicability of educational research findings.

The age distribution of participants also provides insights into the effectiveness of the group discussion method. A majority of the students (64%) were aged between 12 and 15 years, while 36% were older than 15. This indicates that group discussions may be particularly effective for younger learners, who may benefit more from interactive and collaborative methods. Recent research by Elevate K-12 (2024); Gonzalez-DeHass and Willems, (2024) and Park et al. (2024) found that middle-school-aged students are more likely to engage with and benefit from group-based learning environments compared to older students, who may be more accustomed to individualistic learning styles. The findings of this study support this notion, as the group discussion method showed significant improvements in the performance of younger students.

5.1. Impact of Group Discussion on Chemistry Performance

The study's results, as presented in Table 3, show a clear improvement in the academic performance of students who participated in group discussions, particularly when compared to those taught through traditional methods. The data from the experimental group demonstrated significant gains in chemistry performance over time, with a marked increase in the number of students achieving high-range marks during formative and summative tests. Table 8 further validates these findings with a statistically significant difference in posttest scores between the control and experimental. Furthermore, a calculated effect size indicates a medium to large effect according to Cohen's benchmarks which again confirms that group discussions had a meaningful positive impact on student performance in chemistry, indicating the effectiveness of this teaching strategy.

These results are consistent with a growing body of research on collaborative learning. For instance, Allen et al. (2021) conducted a meta-analysis that found group discussions to significantly

improve students' understanding and retention of scientific concepts. Similarly, several studies emphasize the role of peer interaction in deepening students' conceptual understanding in STEM subjects (Jeong et al., 2019; Nungu et al., 2023; Wang & Li ,2024). These studies align with the current findings, reinforcing that group discussions can effectively enhance student learning outcomes in chemistry, especially in topics that require conceptual clarity and application, such as inorganic chemistry.

Moreover, the observed improvements in student performance over time, particularly between FT-1, FT-2, and the summative test, echo findings from Park et al. (2024), which demonstrated that sustained group discussion over multiple assessments leads to higher achievement and retention rates compared to short-term interventions. This underscores the importance of integrating group discussions as a regular pedagogical strategy rather than as an isolated activity. Additionally, the study's findings align with Cavinato and Mullaugh (2022), who noted that group discussions help students bridge gaps in their understanding of complex scientific topics. In this study, the control group, which did not use group discussions, showed modest improvements, whereas the experimental group exhibited a notable leap in achievement. This reinforces the idea that interactive learning approaches like group discussions foster a more profound comprehension of chemistry concepts compared to traditional methods.

5.2. Strategies for Organizing Effective Group Discussions

Effective group discussions depend not only on the method itself, they also rely on how the groups are structured. Tables 4, 5, and 6 highlight the various strategies used by teachers to organize group discussions. The results indicate that 72% of groups were formed based on seating arrangements, while only 18% were grouped by intellectual abilities and 6% by academic interests. While this method of convenience-based grouping is commonly employed, the literature suggests that more deliberate grouping strategies may yield better outcomes. Previous studies have found that when groups are formed based on students' academic strengths and interests, there is a significant increase in collaboration quality and academic performance while others advocate algorithmic based selection (Haq et.al, 2021; Kyprianidou et .al, 2012; Liang et al., 2024)

Students' preferences for group size, as shown in Table 5, overwhelmingly favor smaller groups of four to six members (88%). This preference aligns with the findings of Fay et al. (2000), who demonstrated that smaller groups promote more meaningful interaction and communication. Several studies further support this, showing that smaller group sizes foster a greater sense of responsibility among group members, leading to improved learning outcomes (Michaelsen et al., 2023; Wilkinson, & Fung, 2002). These findings are echoed in this study, where students in smaller groups reported more positive learning experiences and demonstrated better academic results.

Furthermore, teachers' preferences, as indicated in Table 6, suggest a strong inclination (82%) toward random selection of group members, which aligns with prior research that highlights the benefits of teacher-assigned groups. Li et al. (2016) found that random selection can prevent the formation of cliques and encourage diverse interactions among students, leading to more balanced group dynamics. Studies by Mozaffari (2017) and Putzeys et al. (2023) also confirm that teacher-assigned groups, as opposed to self-selected ones, result in more equitable learning environments, especially in mixed-ability classrooms. These findings resonate with the strategies employed in this study, where random group assignments appeared to foster a more collaborative and inclusive atmosphere.

5.3. Effectiveness of Group Discussion in Promoting Student Engagement

Beyond academic performance, the group discussion method also had a significant impact on student engagement, as evidenced by the results in Table 7. The majority of students (56%) reported that group discussions helped them better understand chemistry concepts by allowing them to hear and discuss different viewpoints. Additionally, 22% of students recognized the development of higher-level thinking, social skills, and oral communication through group discussions. These findings are consistent with recent research which emphasized the role of peer

learning in promoting critical thinking and collaborative problem-solving skills (Chang et. al., 2021; Smith, 2023; Topping et al., 2017).

The benefits of group discussions in enhancing student engagement were also highlighted by Roseth et al. (2008), whose meta-analysis found that collaborative learning environments significantly improve student motivation and participation. More recent research demonstrated that students who participated in group discussions were more likely to take initiative in their learning and show higher levels of engagement during lessons (Heflin & Macaluso, 2021; Stanford Teaching Commons, 2024). The results align with these findings, as students in the experimental group showed higher levels of commitment and initiative, as noted by 6% of participants.

The development of social skills and preparation for real-life situations also ties into the broader educational benefits of group discussions. Recent studies by Hennig-Thurau et al (2023) and Yang (2023) have explored the long-term impacts of collaborative learning on students' preparedness for the workforce, finding that students who engage in group discussions during their education are better equipped with the teamwork and communication skills necessary for employment. The findings of the current study further substantiate the value of group discussions in improving academic performance and fostering essential life skills.

Finally, the findings provide strong evidence for the effectiveness of group discussions in improving both academic performance and student engagement in chemistry education. The results align with a growing body of literature all of which highlight the benefits of collaborative learning methods (Allen et al., 2021; Nungu et al., 2023; Wang & Li, 2024; Zuin et al., 2021). The study further demonstrates that group discussions enhance students' understanding of chemistry concepts while also promoting active participation, critical thinking, and social skill development. The strategies for organizing group discussions, particularly in terms of group size and random member selection, further contribute to the success of this pedagogical approach. These findings highlight the importance of carefully structured group discussions as a means to improve learning outcomes and student engagement in science education. As collaborative learning continues to gain traction in educational research and practice, future studies should continue exploring how to optimize group dynamics and instructional methods to maximize student achievement.

6. Conclusion and Future Perspectives

The results offer clear support for the role of group discussions in boosting academic performance and fostering greater student involvement in chemistry learning. The experimental group, which engaged in group discussions, exhibited substantial improvements in formative and summative assessments, as validated by statistical t-tests and the calculated effect size. In contrast, the control group, which adhered to traditional teaching methods, showed only modest gains. Both groups demonstrated comparable performance levels during the diagnostic test, further reinforcing the conclusion that the notable improvements in the experimental group’s posttest scores were a direct result of the group discussion method. These results align with recent studies (Jeong et al., 2019; Wang & Li, 2024; Zuin et al., 2021) which have also highlighted the benefits of collaborative learning methods in enhancing students' comprehension and retention of scientific concepts.

The study further identified several effective strategies for organizing group discussions in chemistry classes. The results show that while students prefer group formations based on seating arrangements (72%), teachers favor random selection (82%). Additionally, the overwhelming majority (88%) of participants preferred group sizes of four to six students, indicating that smaller, more interactive groups are optimal for promoting productive discussions. These findings are consistent with the previous work which emphasized that well-structured group dynamics, including appropriate group sizes and diversity, significantly contribute to the success of collaborative learning environments (Cen et. Al. 2016; Georgopoulou, 2024; Herrera-Pavo, 2021; Yan, 2024). Similar results were reported by Michaelsen et al. (2023) and Wilkinson and Fung (2002) who found that small group discussions lead to better peer interaction and deeper engagement with learning materials, particularly in STEM education.

Group discussions were also shown to play a crucial role in fostering student engagement and participation. A majority of the participants (56%) acknowledged that group discussions promoted peer learning, allowing them to benefit from the exchange of diverse perspectives, thus deepening their understanding of the subject matter. This finding echoes the recent conclusions of Heflin and Macaluso (2021) and Stanford Teaching Commons (2024) which found that group discussions increase students' sense of responsibility, commitment, and active participation in learning. Furthermore, the significant improvements in the experimental group's posttest scores support the research results of Dragnić-Cindrić et al. (2024), Mora et al. (2020) and Tsai et al. (2024), who demonstrated that collaborative learning techniques like group discussions are highly effective in promoting active learning and improving student outcomes in science education. These results also align with recent findings on the cognitive and social benefits of group discussions. Chang et al., (2021), Smith (2023), and Topping et al. (2017) emphasized the role of peer collaboration in fostering critical thinking and problem-solving skills, while in Prata et al.'s (2019) study, results indicated that, when compared with the control, the experimental students increased their levels of behavioral and affective engagement but not their levels of cognitive engagement, personal agency, and total engagement. This is particularly relevant in science education, where students often benefit from discussing complex concepts with their peers to reach a deeper understanding.

From a pedagogical perspective, these findings underscore the need for teachers, particularly in science disciplines like chemistry, to incorporate group discussions as a core teaching method. As Mozaffari (2017) and Putzeys et al. (2023) pointed out, the shift toward more interactive, student-centered learning environments is essential for preparing students for the demands of the 21st century. Furthermore, teachers should consider balancing student preferences with pedagogical best practices when forming discussion groups. Random selection can promote diversity of thought, while appropriate group sizes ensure active participation and effective collaboration. Moreover, group discussions can significantly contribute to the creation of a dynamic and interactive learning environment, where students are more engaged and invested in the learning process. This study's findings corroborate the conclusions of Hennig-Thurau et al. (2023) and Yang (2023), who found that group discussions enhance academic outcomes and foster essential life skills such as teamwork, communication, and leadership. While this study provides robust evidence of the benefits of group discussions, it also highlights the need for further research. Future studies should explore the long-term effects of group discussions on academic performance, particularly over multiple academic years, to assess the durability of these benefits. Additionally, research should investigate the impact of different group formation strategies, such as interest-based or ability-based grouping, on student outcomes. The recent works of Haq et al. (2021), Kyprianidou et al. (2012), and Liang et al. (2024) have shown that grouping students based on their interests or abilities can enhance engagement and learning outcomes in certain contexts, suggesting that more nuanced approaches to group formation could further optimize the effectiveness of group discussions. Furthermore, with the increasing integration of digital tools in education, it is crucial to explore how online platforms and digital collaboration tools can facilitate effective group discussions. Recent studies, such as those by Wang and Li (2024) have begun to examine the role of digital tools in supporting collaborative learning, showing promising results in enhancing student engagement and performance. Exploring how these tools can be integrated into group discussions in chemistry education, both in traditional and hybrid learning environments, will be a valuable area for future research.

This study makes a significant contribution to the growing body of literature supporting group discussions as an effective pedagogical tool and those studies that advocate the use of a relatively longer time intervention to observe meaningful impact. For instance, researchers such as Alam and Mohanty (2024), suggests that the lack of significant improvement in academic achievement may be due to the relatively short duration of the intervention, indicating that a longer intervention period might be necessary to observe meaningful changes in academic performance. It provides clear evidence that group discussions improve academic performance, promote student

engagement, and foster essential cognitive and social skills. By implementing structured group discussions and aligning them with best pedagogical practices, educators can create more interactive and inclusive learning environments that better prepare students for both academic success and real-world challenges.

Declaration of interest: The author declares that no competing interests exist.

Data availability: Data generated or analyzed during this study are available at: https://doi.org/10.6084/m9.figshare.24486685

Ethical declaration: This study does not require ethical approval based on the Rwandan context. This study, which was conducted by in-service teacher in Rwanda private school, is exempt from ethical approval because teachers are permitted to engage in research without explicit permission. This exemption is warranted by recognizing that school leaders possess the authority to authorize teachers, who they oversee, to conduct research within their respective schools.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Appendix 1. Questionnaire

Dear respondent,

I kindly request that you respond to the questions and statements provided to the best of your ability. Your cooperation and contribution towards this research on "**Group Discussions in Secondary School Chemistry:Unveiling Pedagogical Alchemy for Academic Advancement"** is highly appreciated. Please note that all information you provide will be treated with utmost confidentiality, and you are not required to provide your name. Furthermore, you have the right to withdraw from participating in this research at any time, and you may discard this questionnaire if you wish to do so. Thank you for your time and participation. A tick **(√) is placed** in front of the most appropriate item in the provided space. Where you will be asked to give more explanations,
use the space provided.

1) Preliminary data

Section A: Background Information

a. Name of the school b. Class: c. Gender: Female ( ) Male ( )

2) Age

Under 12 years old ( ) From 12 to 15 years old ( ) More than 15 years old ( )

3) How is your chemistry performance in senior two?

Excellent ( ) Very good ( ) Fair ( ) Poor ( )

Section B: Teaching-learning process and effects of group discussion on students' performance in chemistry.

4) Can a lack of chemistry laboratories and equipped school libraries lead to poor student performance?

Yes ( ) No ( )

5) Do you like to study in groups?

Yes ( ) No ( )

6) Does your chemistry teacher help you study in groups?

Yes ( ) No ( )

7) How often do you study chemistry in groups in a week?

Once a week ( ) Twice a week ( ) In each chemistry lesson ( ) None ( )

8) According to you, what are the effects of the group discussion method in learning chemistry?

……
……
……

Section C: Strategies for Organizing Pair and Group Work

9) By which criteria are groups of learning chemistry formed?

Based on academic interests ( ) Based on intellectual abilities ( ) Based on how students sit ( )

Other strategies: ……..

10) In which type of group do you like to work in?

Group of two students (Pair work) ( ) Group of (4-6) students ( )

Group of (6-8) students ( ) Group of (6-8) students ( )

Appendix 2. Interview guides

2.1. For teachers

Self-introduction: My names, University, Purpose of research.

1. What are the challenges you face in the teaching and learning process?
2. What teaching method do you mostly use when you are teaching?
3. In the group of how many students do you think teaching and learning would be most effective?
4. According to you, what are the most effective strategies for enhancing students' performance?

2.2. For head teachers and directors of studies

Self-introduction: Names, university, purpose of study.

-Introduction of the head teacher

Question 1. What are the factors that can most easily lead to students' poor performance?

Question 2. There are several teaching methods in chemistry, such as the lecture method, group discussion, demonstration and class practice. Which one do you think is the most effective in enhancing students' performance?

Question 3. In what ways do you think the group discussion method could be improved?

Appendix 3. Sample lesson plan

Lesson Plan 4 (*see the last page*)

Name of teacher/researcher: Theophile Shyiramunda Registration number: 215033383

Subject: Chemistry,

Students' level: Senior two

Topic: Chemical reactions *Subtopic:* Types of reactions

Upon completion of this lesson, students will have the ability to accomplish the following learning objectives:

- The appropriate matches between a given table of chemical reactions and their respective types of reactions can be accurately identified.
- The simple displacement and double displacement reactions can be effectively distinguished with precision.